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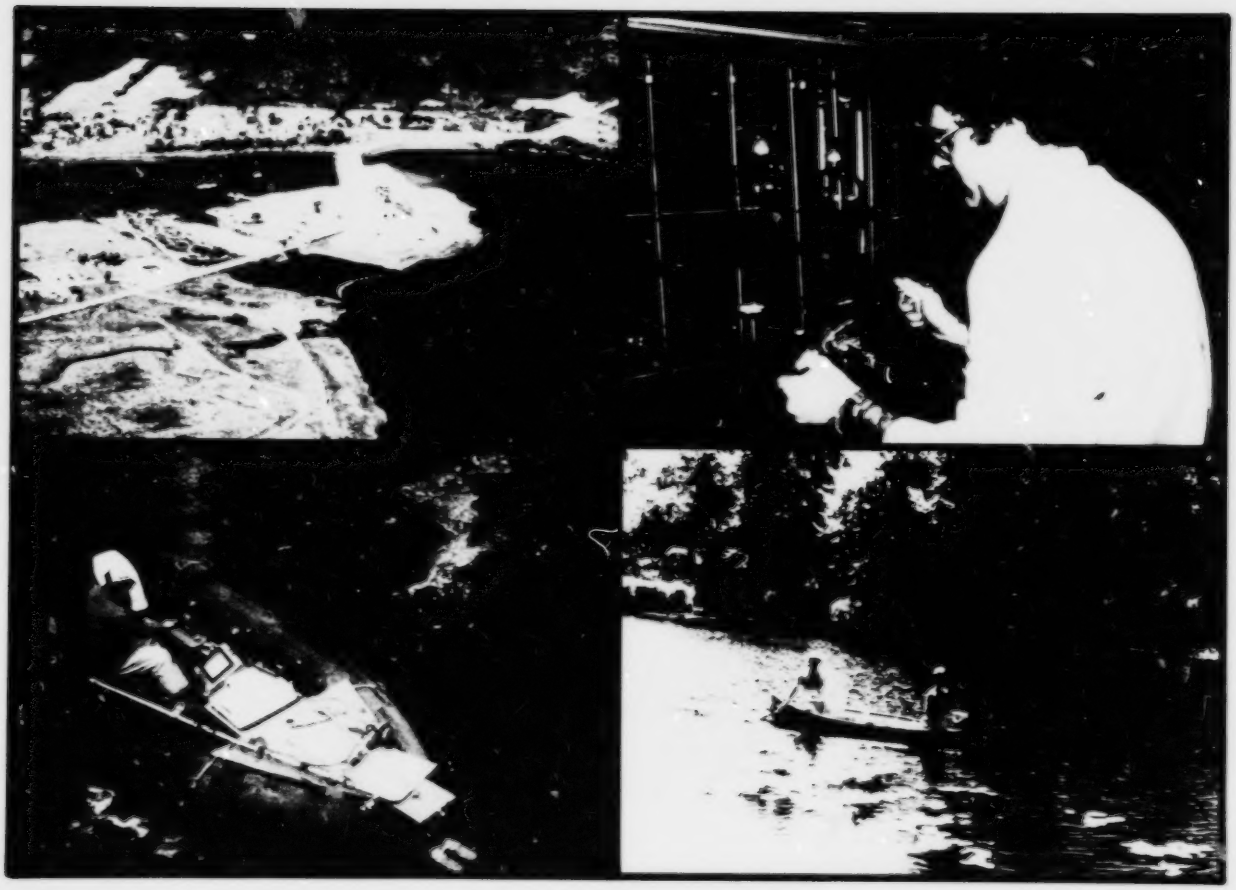

Canada

INLAND WATERS DIRECTORATE
ATLANTIC REGION
WATER RESOURCES BRANCH
DARTMOUTH, NOVA SCOTIA

MEAN MONTHLY RUNOFF ESTIMATION AT UNGAUGED SITES USING THE SQUARE GRID TECHNIQUE

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ABSTRACT

The square grid technique has been used in the past for assessing water resource potential as well as for planning hydrometric networks. The method can be extended to generate synthetic streamflow on ungauged streams. The technique was developed initially for obtaining co-ordinated maps of precipitation, evaporation and runoff on a long-term mean annual basis. The technique was extended to the estimation of the same hydrological elements on a monthly basis (Solomon, 1984).

This paper presents the application of the square grid technique to the estimation of mean monthly runoff in a pilot area in Nova Scotia. The pilot area chosen was the location of a proposed gas pipe line in anticipation of future data needs for ungauged locations along the proposed route. The square grid model is calibrated for eight hydrometric basins within the study area and verified and assessed on three gauged basins. This system can be used to store, process and retrieve information and may have numerous applications in the field of hydrology.

The square grid computer program was purchased by the Water Resources Branch, Ottawa, and details needed to run the routines were not included. As part of this project it became necessary to expand on the consultant's documentation, hence, the section on "Program Input Files" is included in the main text.

RESUME

La méthode du quadrillage fut utilisée antérieurement pour évaluer le potentiel hydrique ainsi que pour planifier les réseaux hydrométriques. Il est possible de développer cette méthode pour qu'elle produise des débits synthétiques pour des rivières non-jaugées. A priori, la technique pouvait produire des cartes qui fournissaient des valeurs annuelles moyennes pour la précipitation, l'évaporation et le ruissellement. Par la suite, la technique fut travillée pour permettre le calcul de ces mêmes valeurs hydrologiques, mais cette fois-ci, sur une base mensuelle (Solomon, 1984).

Ce rapport démontre l'utilisation de la méthode du quadrillage pour calculer le ruissellement des bassins néo-écossais qui se trouvent dans une zone le long du trajet proposé pour le gazoduc. Ceci permettra de fournir les données requises pour les bassins non jaugés si jamais le projet devait aboutir. Le modèle informatique utilisant la méthode du quadrillage fut calibré en utilisant les données de huit bassins hydrométriques de la zone ci-haut mentionnée et ensuite evalué et vérifié avec l'aide de trois autres bassins de la même zone. Le modèle permet l'emmagasinage, le traitement et le retrait des données et pourrait s'avérer utile de plusieurs façons dans le domaine de l'hydrologie.

Le programme informatisé fut acheté par le bureau d'Ottawa de la Direction des ressources en eau. Les modalités pour faire fonctionner le programme n'étaient cependant pas inclues et il fut donc nécéssaire d'élaborer les directives de l'auteur du programme, ce qui explique la partie du rapport intitulée "Fichiers d'entrée du programme" ("Program Input Files").

ACKNOWLEDGEMENTS

Acknowledgement is given to Steven Ryan and Tod Rawding, Environment 2000 employees, responsible for the collection and storing of physiographic data for the Nova Scotia pilot study.

The collection of physiographic data for New Brunswick was made possible through funding provided by Employment and Immigration Canada under its Canada Works Programs of 1984 and 1985. Special thanks are expressed to Alan Moase, the Canada Works employee responsible for the collection of the data base for New Brunswick.

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MEAN MONTHLY RUNOFF ESTIMATION AT UNGAUGED SITES USING THE SQUARE GRID TECHNIQUE

1.0 INTRODUCTION

1.1 Purpose

The purpose of this project is to test and evaluate the regression/square grid technique (reference 1) for the estimation of mean monthly flow data in an area of northeastern mainland Nova Scotia and to evaluate the feasibility of the program for regional application, i.e. technical considerations, costs, value to users, and user friendliness of the program.

1.2 Scope

The scope of this project is as follows:

(1) To use the square grid program developed by Solomon et al (reference 2).

(2) To select an area in Nova Scotia with 4 to 8 hydrometric stations within it. The area should be relatively homogeneous.

(3) To choose a base period having concurrent streamflow and climatologic records with at least ten years of data.

(4) To collect, tabulate, code and create computer files of physiographic, climatic and hydrologic data on a 2 km x 2 km grid using the Transverse Mercator Projection Topographic Map Series at a scale of 1:50,000.

1.3 The Regression/Square Grid Program Technique

The square grid program uses multiple linear regression to produce regional estimates of precipitation, temperature and runoff from physiographic parameters. The average value of precipitation, temperature, evaporation and runoff for each square element of the grid system is then computed using the regression equations obtained. The square grid technique has been used in Canada as a means of spatially distributing streamflow and precipitation values. The technique relies on a distributed model of precipitation/runoff and considers temporal, spatial and measurement errors as controlling the accuracy of the regionalization. It should be noted that the model or regression equations developed can be the largest source of error. For more details regarding the technique, see Solomon et al (reference 1).

Other programs are needed to perform specific tasks, i.e. to calculate flow direction, average slope and azimuth from the elevation data. These parameters may be needed as input to the square grid program if further spatial refinement of the output is required.

1.4 Accuracy

The use of the technique is, in addition to the above errors, limited by the accuracy of the mapping, the accuracy of establishing watershed boundaries, etc.

The scale variation in a mapped area extending through 1/2° or less in latitude or longitude causes errors which are less than those due to other unavoidable causes and so may be disregarded.

The error introduced by representing the arc of a parallel or of a great circle of five minutes (5') or less in length by a straight line may also be neglected, see "Drainage Area Determination", reference 3.

A correction factor to the map scale can be applied. The map area (the earth area represented by the map) is calculated using the equation for the 1929 Smithsonian Geographical Tables for the Universal Transverse Mercator co-ordinates. The equation gives the area on the earth defined by the latitudes and longitudes of the 4 corners of the map. Due to the 2 km x 2 km grid chosen this correction is not thought to be warranted and is not applied.

The optimum grid interval is determined by the size of the area, the size of the individual drainage basins being considered, the details of the available data, the available computer characteristics and the purpose and budget of the study, etc. For most problems, grid intervals between about one and ten kilometres are considered. In general, if the ratio between the size of the drainage area considered and the area of one grid square is larger than six, the accuracy is sufficient for practical purposes.

Another source of error is the hydrometeorologic data. The long-term monthly means (runoff, precipitation, temperature) all have their own sampling errors.

2.0 METHODOLOGY

2.1 The Grid System

As implied in the term "grid square", this technique (reference 4) entails dividing the study area into a uniform grid, the sections of which are identified in cartesian co-ordinates (I, J).

This procedure facilitates identification of individual grid squares and selected groupings of grid squares as well as storage and retrieval of grid square information. The size of the selected grid is dependent on the relative physical size and variability of the study area. In Nova Scotia, a 2 km x 2 km grid square was considered optimal.

Transverse mercator projection maps of the Nova Scotian area on a scale of 1:50,000 employ the 2 km x 2 km square grid division system. Use of these transverse mercator projection maps in studies of large areas does, however, cause some distortion at mercator region divisions. In Nova Scotia, these divisions are located at 60° and 66° longitude. These distortions are small when employing a 2 km x 2 km grid. Also, these projections affect a very minor portion of Nova Scotia and for this pilot study the mercator divisions are not considered to be a factor.

2.2 Physiographic Parameters

Basic physiographic data for each square in the study area (see Figure 1) were extracted from the transverse mercator projection maps. These data included areas of lake, forest, swamp, open land and sea in each grid square, four elevations per grid square, and the shortest distance to the sea from the centre of the basin in eight directions.

The eastings and northings of each grid were also recorded. The procedure used to collect the physiographic data set is described by A. Moase (reference 5).

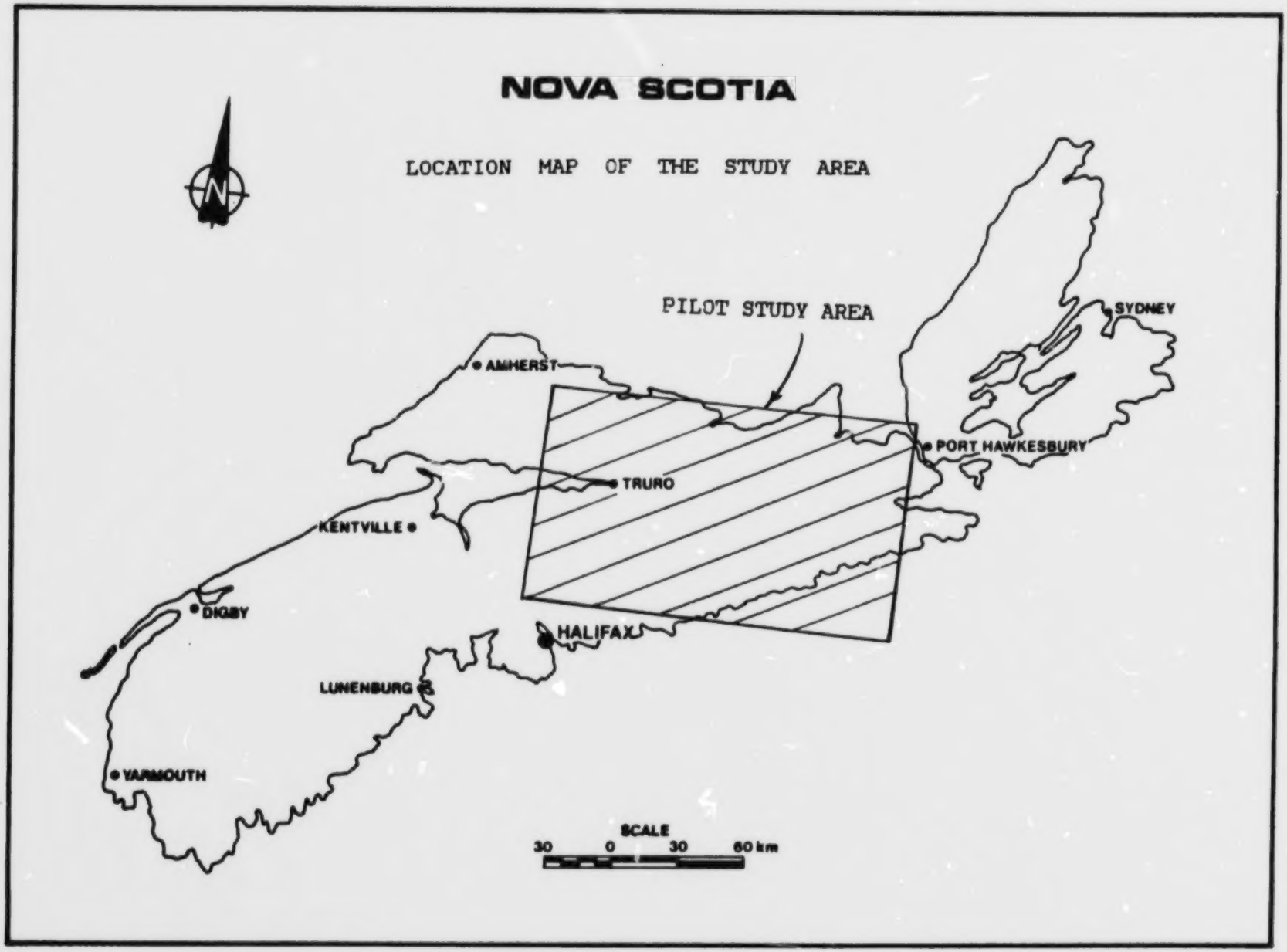
NOVA SCOTIA
LOCATION MAP OF THE STUDY AREA
N
PILOT STUDY AREA
SYDNEY
AMHERST
PORT HAWKESBURY
TRURO
KENTVILLE
DIGBY
HALIFAX
LUNENBURG
YARMOUTH
SCALE
30 0 30 60 km

FIGURE 1

2.3 Recorded Streamflow Data

Streamflow data recorded in the study area (see Table 1) were collected and stored. The historical records at eight gauging sites (see Figure 2) were selected for use in the study on the basis of the length of record; the period used in this study is 1966 to 1982, inclusive.

The river basins gauged by the eight calibration stations were delineated and the grid areas completely or partially contained in the watersheds were identified for use in determining average basin characteristics. Three river basins (Table 1) were used to verify the regression equations.

HYDROMETRIC STATIONS USED IN THE STUDY

PERIOD OF RECORD, 1966 TO 1982

CALIBRATION

Station No.	Location	Drainage Area (km^2)
01DG003	Beaver River near Kinsac	96.9
01DH003	Fraser River near Archibald	9.07
01DN004	Wallace River at Wentworth Centre	298
01DP004	Middle River at Rocklin	92.2
01DR001	South River at St. Andrews	177
01EN002	Liscomb River at Liscomb Mills	389
01EO001	St. Marys River at Stillwater	1350
01ER001	Clam Harbour River near Birchtown	45.1

VERIFICATION

Station No.	Location	Drainage Area (km^2)	Period Used in Study
01DG018	Pembroke River at Glenbervie	73.3	1978-84
01DO001	River John at Wolsford	249	1966-82
01DR003	Rights River near Antigonish	64.2	1978-84

Note: The period of record for some of the verification stations differs from the calibration stations. This was due to the lack of stations, within the study area, with sufficient record length.

TABLE 1

LOCATION OF HYDROMETEOROLOGICAL STATIONS USED IN THE STUDY

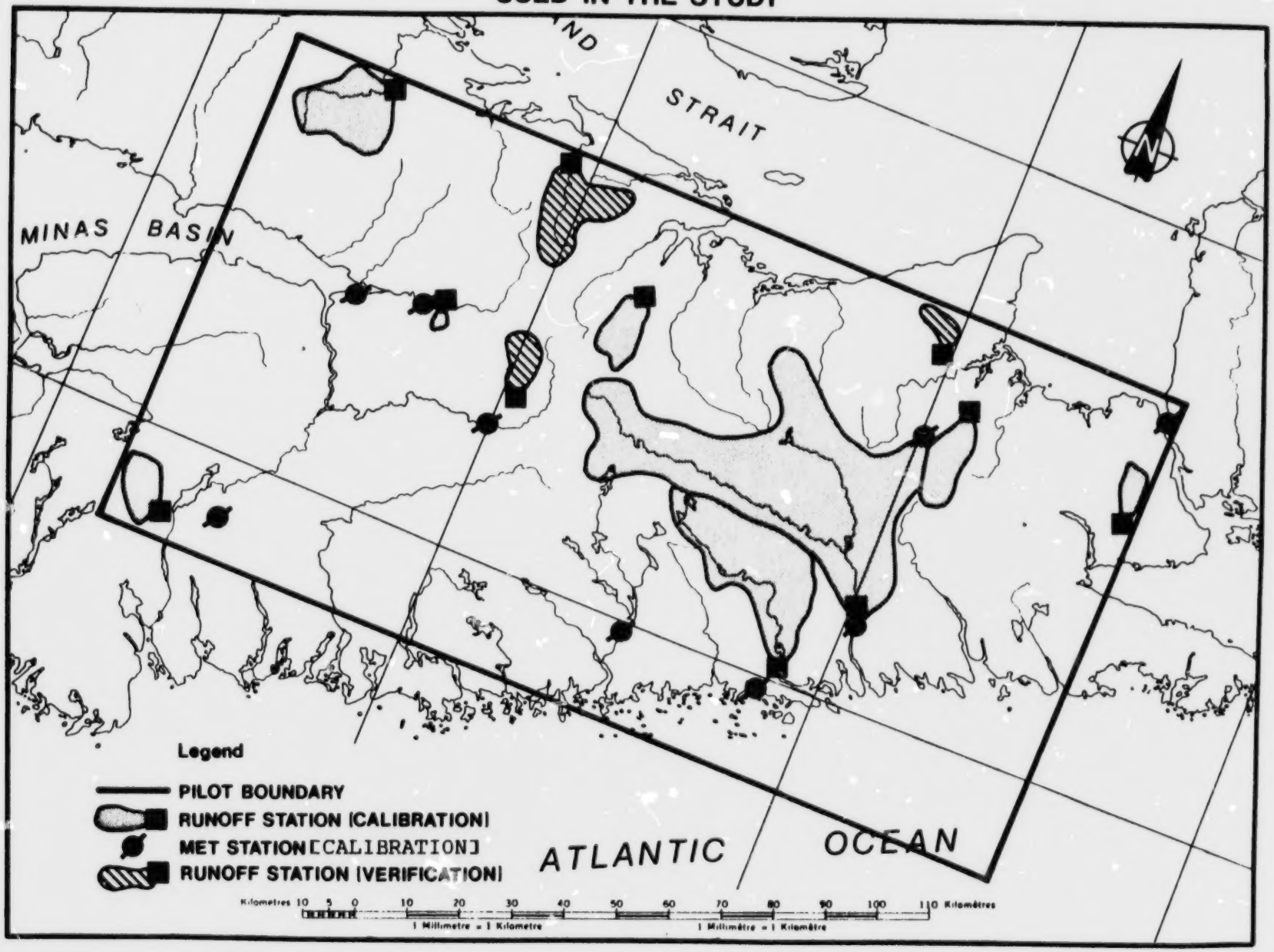

FIGURE 2

2.4 Recorded Meteorologic Data

Meteorologic data were also examined. Precipitation and temperature records (see Table 2) were selected on the same basis as was the streamflow data. The grids that each station occupied were also identified and the basic physiographic data extracted. Figure 2 presents the location of the meteorologic stations.

3.0 SQUARE GRID/REGRESSION ANALYSIS

3.1 Procedure

It was immediately recognized that, since the computer model acquired was developed for the Amazon River basin, the model did not include a snowmelt subroutine which is absolutely necessary for applications in Canada. Such a subroutine could be readily added using the same relationship as is proposed for a distributed rainfall - runoff model also acquired by the Water Resources Branch, Headquarters. The basic assumptions are that:

(a) Precipitation is considered to be snow when temperature is below 2°C.

(b) Snowmelt is occurring according to a degree day snowmelt relationship.

The square grid/regression analysis procedure is described in detail in Appendix A.

A summary of the procedure* is described as follows:

* From reference No.4

METEOROLOGIC STATIONS USED IN THE STUDY
PERIOD OF RECORD, 1966 TO 1982

CALIBRATION

Station	Location Latitude and Longitude	
Stillwater Sherbrooke	45°09'N	61°59'W
Upper Stewiacke	45°13'N	63°00'W
Clifton	45°21'N	63°25'W
Collegeville	45°29'N	62°01'W
Ecum Secum	44°58'N	62°09'W
Ruth Falls	44°56'N	62°30'W
Port Hastings	45°38'N	61°23'W
Halifax Int'l "A"	44°53'N	63°31'W
Truro	45°22'N	63°16'W

TABLE 2

(1) Using data from selected meteorologic stations a relationship is developed between mean monthly temperature at the station and corresponding grid square physiographic characteristics. This is established by a regression equation. The equation is used to estimate the mean monthly temperatures in the remaining squares. A similar analysis is used to make a preliminary estimate of the mean monthly precipitation in each square.

(2) Preliminary evaporation is estimated for each square by using preliminary temperatures, precipitation and the Turc's formula.

(3) Preliminary estimates of precipitation and evaporation are then used to calculate a preliminary value of mean monthly runoff for each square of the watersheds having flow data.

(4) The grid square runoff established in step (3) is used to compute preliminary average runoff for each basin having flow records and coefficients "R" representing the ratio between the recorded and computed average flows are established.

(5) A new precipitation value is computed for each square of basins having flow data, "R" being used as a correction factor, i.e., Precipitation (corrected) = R x Runoff + Evaporation.

(6) By using the corrected values for precipitation in each square and the precipitation data at the rain gauging station, the relationship between precipitation and physiographic factors is established by a new regression equation.

(7) The procedure is then repeated as often as necessary to obtain an "R" value as close to "1" as is considered reasonable.

(8) Once grid square runoff, precipitation, and evaporation values are finalized in gauged areas, the runoff and precipitation

distributions in ungauged areas are estimated by means of regression equations established from final precipitation and runoff relationships in gauged areas.

4.0 SQUARE GRID PROGRAM

4.1 Program Input Files

The square grid computer program (reference 2) used in this study was developed for hydrometric network planning studies and applied to the Tocantins Basin, a major river of the Amazon drainage system. The program required considerable time to be revised and understood for the Nova Scotia application. The program computes regional estimates of hydro-climatologic parameters from relationships with physiographic characteristics.

The working procedure and program logic are presented in Appendix B, section (A). The descriptions of the programs and files employed are presented in Appendix B, sections (B) and (C), respectively. The data files, needed as input, are documented in file, "MWBALFIL.DOC" on the Water Resources Branch PDP11/44 computer at Dartmouth, N.S. The programs are documented in file, "NWBALPGM.DOC" and the cross reference table of all files and programs is in file, "XREF.DOC". Readers wanting to apply this technique should contact the Water Resources Branch, Hydrology Division, for access to these files.

The following files are used to conduct this study.

(1) BRAZMAST.FMT - This is the master file containing the physiographic data set, i.e. the grid eastings and northings, column and row numbers, the grid areas, the four corner

elevations of the grids and the grid surface features (wooded, barren, swamp, fresh water and sea water areas).

(2) HGRIDO.FMT - This is the hydrologic grid file, containing the gauging station identification numbers, the record number of the grid in the master file, the column and row numbers and grid area. This file contains the information for the total basin,i.e. all the grids for a gauged basin.

(3) HGRIDD.FMT - This file contains the same information as the above file, HGRIDO.FMT; but for grids of gauged sub-basins which do not appear in any other sub-basin upstream, i.e. differential areas. In this study, there are no gauged sub-basins, hence, HGRIDD.FMT is the same as the HGRIDO.FMT file.

(4) BRAZINDX.FMT - This is the index file to the master file (physiographic file). Although the squares are stored in an orderly fashion in the physiographic file (by column and row), only the squares of interest are stored. This file has a unique record assigned to each square in the matrix regardless whether it is of interest or not. Each index record contains a pointer to the master file, such that the master file can be directly accessed by means of column and row numbers.
The matrix (for the pilot study) starts at column No. 1 and row No. 1, i.e. (I, J) =(1, 1). To convert the eastings and northings to the I, J co-ordinate system the following transform was used:

$$I = (E - 436)/2$$
$$J = (N - 4960)/2$$

where, I = column #
J = Row #
E = easting
N = northing

(5) BRAZSTA.AL - This is the ALPHA (α) data file. The ALPHA value is a storage characteristic of the gauged basin. This value was determined using the following relationship:

$$\alpha = -\ln[Q_t/Q_{t-1}] \times 10^3$$

where, α = alpha value;
ln = natural logarithm;
Q_t = monthly mean runoff for the month with the lowest monthly precipitation for the period 1966-82;
Q_{t-1} = monthly mean runoff for the month previous to Q_t.

The alpha value was calculated for the drainage basins used in the calibration (see Table 1). The alpha values are used internally by the square grid program during regression runs and when performing water balances.

(6) BRAZTEMP.FMT - This file contains the station identification numbers, easting and northings, and the mean monthly temperature values in ^{o}C, from January through December for the meteorologic stations presented in Table 2.

(7) BRAZPREC.FMT - This file contains the station identification numbers, easting and northings, and the mean monthly precipitation values in millimetres, from Janury through December for the meteorologic stations presented in Table 2.

(8) BRAZFLOW.TOT - This file contains the hydrometric station identification numbers and the mean monthly runoff values in millimetres, from January through December for the stations shown in Table 1.

(9) BRAZIDEN.DAT - This file contains the labels of all the independent variables used in the regression program as follows:

1 Column Number
2 Row Number
3 Easting

4	Northing
5	Grid Area (km^2)
6	Elevation (NW) (ft.)
7	Elevation (SW) (ft.)
8	Elevation (SE) (ft.)
9	Elevation (NE) (ft.)
10	DTO (N) (km)
11	DTO (NE) (km)
12	DTO (E) (km)
13	DTO (SE) (km)
14	DTO (S) (km)
15	DTO (SW) (km)
16	DTO (W) (km)
17	DTO (NW) (km)
18	Wooded area x 100 (km^2)
19	Barren area x 100 (km^2)
20	Swamp area x 100 (km^2)
21	Fresh water area x 100 (km^2)
22	Sea area x 100 (km^2)
23	Not used
24	Not used

NOTE: Parameters 10 through 17 are not used in this study.

4.2 PROGRAM OUTPUT

In Appendix B, section (D), is presented an output listing for the Nova Scotian pilot study. This listing represents the first 30 steps shown in section (A) of Appendix B. The analyses are computed

for the month of May (shown as month i in the working procedure). The month (i - 1) represents the previous month which is also used to compute the monthly estimates for the month of interest, i.e. for this example, the month of May.

In steps 31 to 36 of the working procedure a new month is started.

The square grid model was calibrated using eight (8) hydrometric and nine (9) meteorologic stations. Also, the physiographic grid data for the hydrometric gauged basins shown in Figure 2 were used to develop the regression equations. The physiographic data set outside the gauged basins in the pilot area was not used. The boundary grids of the basins were included in whole with the enclosed basin grids, i.e. grids inside the drainage basin delineations. Therefore, a small percentage of some basins modelled include out-of-basin areas.

The meteorologic data regressions were calculated using the physiographic parameters associated with the grid where the meteorologic station is located.

4.3 DISCUSSION OF RESULTS

Using the data at the selected hydrometric and meteorologic stations, regression equations were established between mean monthly temperature, precipitation and runoff and the corresponding grid square physiographic characteristics.

The regression equation relating parameters of mean monthly flow for May at gauged sites to basin physiographic characteristics is presented in Appendix B, section (D). The initial month of May was selected because it is out of the ice

producing backwater period in Nova Scotia and May is a relatively high flow month. The more spatially uniform flow that occurs in May is assumed to support better model results.

The analyses are based on a forward stepwise linear multiple regression. The number of independent variables equals eleven and the dependent variable is runoff for May.

The statistics of the physiographic and dependent variable for all grids in all the calibration basins are presented as follows:

Variable Number	Mean	Standard Deviation	
1	51.438	22.928	Column Number
2	30.703	9.894	Row Number
3	452.695	180.662	Elevation (NW) (ft.)
4	459.238	186.470	Elevation (SW) (ft.)
5	463.377	304.194	Elevation (SE) (ft.)
6	445.669	184.720	Elevation (NE) (ft.)
7	367.960	39.621	Wooded area x 100 (km^2)
8	15.992	33.629	Barren area x 100 (km^2)
9	6.538	16.954	Swamp area x 100 (km^2)
10	9.282	18.536	Fresh water area x 100 (km^2)
11	0.132	3.639	Sea area x 100 (km^2)
12	126.016	53.553	Runoff (dependent variable) (mm)

The constant to limit the number of variables entered into the stepwise regression is set at 0.04 (4 percent). The constant represents the proportion of the variance which should be explained. This means that if the next variable to be entered in

the regression explains less than 4 percent of the total variance, the regression stops. A constant of zero percent will force all the independent variables into the regression.

The only independent variable entered into the equation explaining more than 4% of the variance for May is the swamp area. The equation for estimating the mean monthly runoff for May is as follows:

$$\text{Runoff (May)} = -2.246a + 140.703$$

where, a = swamp area x 100 (km^2)

The standard error of estimate of the relationship is:

$$\text{S.E.}(\%) = \text{S.E.}/\bar{X} \cdot 100\% = \frac{37.7}{126} \times 100 = \pm 30\%$$

where, S.E. = standard error of estimate

(adjusted for degrees of freedom)

$\bar{X}$ = mean value of the runoff (May).

The multiple correlation coefficient (adjusted for degrees of freedom) is 0.711.

Table 3 presents a summary of the results of the mean May flow estimates for the calibration stations used in this study.

Table 4 presents the summary of the regression statistics (goodness of fit) for the open water months, May through November.

The months of traditional backwater affected streamflows were not used in the calibration. In addition the model as mentioned previously does not contain a snow accumulation/melt routine, therefore, these months are not considered.

RESULTS OF CORRELATIONS BETWEEN HYDROLOGIC AND PHYSIOGRAPHIC CHARACTERISTICS OF GAUGED WATERSHEDS FOR MAY

CALIBRATION

Station	Computer I.D. No.	Runoff (mm) Recorded	Runoff (mm) Estimated	K Factor (%)
South River (St. Andrews)	100	100	133	-25
Clam Harbour River	200	131	96	37
Fraser Brook	300	107	139	-23
Middle Brook (Rocklin)	400	116	123	-5
Wallace River	500	132	131	1
Liscomb River	600	145	125	16
St. Marys River	700	126	125	1
Beaver River (Kinsac)	800	105	138	-24

Mean K Factor = ±17%

Standard Deviation = ±13%

$$K = \left[\frac{\text{Recorded Runoff} - \text{Estimated Runoff}}{\text{Estimated Runoff}}\right] \times 100\%$$

TABLE 3

SUMMARY OF THE REGRESSION STATISTICS

MAY THROUGH NOVEMBER

Statistics	May	June	July	August	Sept.	Oct.	Nov.
# of independent variables entered into the equation	1	2	2	2	2	2	2
Multiple correlation coefficient	0.711	0.723	0.715	0.772	0.726	0.781	0.776
Standard Error of Estimate (%)	±30	±32	±34	±31	±35	±26	±26

Note: The independent variable found in all of the above months is swamp area x 100 (km^2); the second independent variable for months June to November inclusive, is row number (latitude).

TABLE 4

A verification of the regression equations was considered necessary. The use of the equations to estimate mean monthly runoff in ungauged areas is the original purpose. Therefore, as a test, the equations were solved for independently gauged areas considered to be within the same homogeneous zone. This is to give an indication of just how well the equations modelled the actual runoff.

The three verification basins are listed in Table 1 and the location of the basins are presented in Figure 2.

The recorded mean monthly runoff in millimetres and the estimated values are presented in Table 5 for May through to November, inclusive. The percent difference between the recorded and estimated runoff values are also presented in this table. The errors for the three verification basins ranged from 2 to 195 percent for May through to November. The mean error is 63 percent with a standard deviation of 52 percent.

The regression equations used to produce the estimated runoff in Table 5 are presented in section (E) of Appendix B.

The results of the square grid technique were compared to a very simple proration technique. Table 6 presents the comparison of the two methods. The errors of the proration method ranged from zero to 91 percent with a mean of 35 percent.

RESULTS OF THE VERIFICATION RUNS

Station	Number	Runoff* (mm) Recorded		Runoff* (mm) Estimated		Percent Error* (%)	
River John at Welsford 1966 to 1982	01DO001	109	13	125	36	15	177
		32	51	57	91	78	78
		17	98	35	147	106	50
		20		59		195	
Pembroke River at Glenbervie 1978 to 1984	01DG018	95	36	135	29	42	-19
		44	63	51	78	16	24
		34	99	30	130	-12	31
		44		45		2	
Rights River near Antigonish 1978 to 1984	01DR003	93	22	139	40	49	82
		29	80	64	102	121	28
		24	105	40	164	67	56
		40		67		68	

*Note: The information within each block represents the data for May to November; presented as shown below:

May	Sep
Jun	Oct
Jul	Nov
Aug	

TABLE 5

COMPARISON OF SQUARE GRID RESULTS WITH A SIMPLE PRORATION TECHNIQUE

MEAN MONTHLY RUNOFF in m^3/s

Station	Period	Month	Recorded	Estimated By Prorating[1]	% Error	Estimated By Square Grid	% Error
River John at Welsford 01D0001	1966-1982	May	10.2	9.30	-9	11.7	15
		Jun	3.10	3.50	13	5.51	78
		Jul	1.58	2.11	34	3.25	106
		Aug	1.87	3.42	83	5.51	195
		Sep	1.25	2.18	74	3.46	177
		Oct	4.75	5.99	26	8.46	78
		Nov	9.45	11.6	23	14.2	50
Pembroke River at Glenbervie 01DG018	1978-1984	May	2.60	2.29	-12	3.69	42
		Jun	1.23	1.08	-12	1.43	16
		Jul	0.934	0.515	-45	0.821	-12
		Aug	1.21	0.658	-46	1.23	2
		Sep	1.02	0.542	-47	0.830	-19
		Oct	1.72	1.10	-36	2.14	24
		Nov	2.81	2.69	-4	3.68	31
Rights River near Antigonish 01DR003	1978-1984	May	2.23	2.35	5	3.33	49
		Jun	0.718	0.968	35	1.59	121
		Jul	0.576	1.10	91	0.961	67
		Aug	0.961	1.35	40	1.61	68
		Sep	0.544	0.793	46	0.991	82
		Oct	1.92	0.740	-61	2.45	28
		Nov	2.61	2.60	0	4.06	56
				|Mean| =	35%	|Mean| =	63%
				|S.D.| =	26%	|S.D.| =	52%

1. Note: Mean monthly flows for River John at Welsford and Rights River near Antigonish were both computed by prorating flows from 01DR001, South River at St. Andrews. Flows for Pembroke River at Glenbervie were computed from flows at 01DG003, Beaver River near Kinsac.

TABLE 6

5.0 SUMMARY

5.1 Conclusions

From the material presented in this report, it appears that the grid square technique can be usefully applied to the problem of generating hydrologic data on ungauged streams. The technique facilitates storage and retrieval of the large amounts of data required in such work and provides an efficient method of integrating climatologic, hydrometric, and physiographic data to estimate model parameters (reference 6).

In view of the results listed in Tables 3 to 6, the author feels that they are encouraging. The comparison using the proration technique shows that this simple method produces better results than the square grid technique. This would be true only where the stations are spatially close and in a homogeneous area. Prorating data over long distances in areas not having a good hydrometric network, it is believed, would not produce results as well as the square grid method. Also considering the effort associated with the collection and computerization of the climatologic, hydrometric, and physiographic data sets, further work with the technique is merited and justified.

It should be emphasized that little documentation existed with the use and application of the square grid program described herein. Considerable time was required to sort out the many files required by the program. A short contract was required to have the program developer explain items not able to be resolved. Also, the technique does not include a snowmelt subroutine which is absolutely necessary for applications in Atlantic Canada.

Utility programs are needed with this technique for maps printed or drawings of the estimated mean monthly precipitation, evaporation and runoff. The regression equations of the above parameters are now developed and stored for future use. Input and advice may still be needed from the program developer or another programmer regarding the above utility programs to be interfaced with the square grid technique.

The square grid technique from a technical viewpoint has been developed and used successfully by others (references 1, 2, 4, 6); its usefulness in the Atlantic Provinces has been demonstrated by Solomon et al and Cuthbert. Reitering previous statements, a snow-melt subroutine is needed to generate mean monthly runoff for winter months using the programs in this report. The cost of using this application is basically the cost of collecting the physiographic data, which (approximately) is 2 to 3 person days to collect and computerize (9 to 10 pieces of physiographic information) from one map sheet at 1:50,000 scale and 2 x 2 km^2 grids.

The square grid technique has potential value in generating mean monthly runoff for ungauged basins in the Atlantic Region, but considerable work is still needed to make the computer programs employed in this report user friendly.

5.2 Recommendations

(1) It is recommended that utility programs be developed to interface with the square grid technique to make the program output more usable.

(2) It is recommended that a snowmelt subroutine be incorporated into the technique.

(3) It is recommended that the square grid technique for the estimation of mean monthly runoff be made user friendly.

(4) It is recommended that the Water Resources Branch further develop this technique as a long-term tool for data transfer and as a common data file accessible for other hydrologic problems.

6.0 THE NEW BRUNSWICK EFFORT

The Water Planning and Management Branch of Inland Waters/ Lands, Atlantic Region, have been developing a comprehensive capability for evaluating water supply and demand in the Region. A national water supply/demand forecasting computer model is being used to achieve this task. The Province of New Brunswick was chosen to initiate the project as a well established data base is available for the water supply/demand model.

The supply portion of the national model requires estimates of mean monthly runoff values by basin. The square grid technique was looked upon as one vehicle for providing this information.

As a result of the Canada Works Programs of 1984 and 1985, manpower was made available by the Water Planning and Management Branch for the collection of the physiographic data needed as input to the square grid program.

The physiographic characteristics (similar to the Nova Scotia effort) for the Province of New Brunswick have been collected and tabulated. All the physiographic data for the province of New Brunswick have been computerized.

The climatologic data have also been tabulated and summarized. The period of record and the stations used for the New Brunswick work are those as published in the Atmospheric Environment Service publication, "Canadian Climate Normals, Temperature and Precipitation, 1951-1980", AES, Environment Canada, Atlantic Provinces.

The hydrometric data set included all stations with 10 years or more of data. The (I, J) co-ordinates of all the grids of the

gauged basins have been tabulated and summarized.

The data sets needed to run the square grid program throughout New Brunswick have been collected and tabulated, although, not necessarily computerized. Appendix C presents the format used to store the physiographic data set on the PDP11/44 computer at Dartmouth, Nova Scotia.

7.0 REFERENCES

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2. Solomon, S.I., "Extension of Square Grid Technique to the Estimation of Monthly Co-ordinated Maps of Precipitation, Evaporation and Runoff", Draft Report, 1984.

3. Reid, I.A. and D.M. Stone, "Drainage Area Determination", Technical Memorandum No. 1, Department of Northern Affairs and National Resources, Water Resources Branch, Ottawa, 15 November, 1960.

4. Cuthbert, D.R., "Hydrologic Analysis of the New Brunswick Region by the Grid Square Technique". Engineering Division, Water Planning and Operations Branch, Department of Energy, Mines and Resources, Ottawa, Canada, 1970.

5. Moase, A., "Physiographic Data Acquisition for Grid Square Analysis", A Report Prepared under the Canada Works Program, Contract No. 1829-DE6, October, 1985.

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APPENDIX A

SQUARE GRID/REGRESSION ANALYSIS

PROCEDURE

The square grid/regression analysis procedure* is described in detail as follows:

(1) Obtain mean monthly values of precipitation, temperature and flow for basins at as many stations as possible in the area studied for which a square grid data bank is available;

(2) Extend precipitation, temperature and flow data by linear trivariate regression analysis to the longest possible common period of record. Divide flow stations into a 2/3 calibration sample and 1/3 validation sample;

(3) Obtain from river basin file the average physiographic characteristics of all basins used in the study (both for calibration and validation samples);

(4) Obtain square grid physiographic data for the whole study area;

(5) Obtain daily flow values and use the recession curve technique to estimate the value of α (alpha) in all small basins (having a drainage area of the same order of magnitude as the individual square); alpha value in this report determined on a monthly basis;

(6) Correlate values of α for calibration basins to their physiographic characteristics, including drainage area;

(7) Estimate, using results from (6), the value of daily α for each square of each basin included in the calibration sample. To use α values for a given month, multiply daily α values by the number of days in the given month;

* From reference No. 2

(8) Select starting month i (for example start with May);

(9) Calculate correlation between runoff of month i $-\Delta t$ (i.e. April) and the average physiographic characteristics of the corresponding basins;

(10) Estimate using results from (9) the values of runoff for month i $-\Delta t$ for squares included in the river basins of calibration sample;

(11) Calculate correlation between precipitation of month i and the physiographic characteristics of the squares in which the corresponding station is located;

(12) Estimate using the results obtained in (11) the values of the precipitation in month i in each square of the calibration sample;

(13) Calculate correlation between the temperature of month i and the physiographic characteristics of the square in which the corresponding stations are located;

(14) Estimate using the results obtained in (13) the values of the temperature in each of the squares of the calibration basins;

(15) Estimate for each square of calibration basins the values of E_i (evaporation in month i) using the results obtained in (10), (12) and (14);

(16) Estimate using the results obtained in (10), (12) and (15) the runoff values for month i in each square of the calibration basins;

(17) Estimate using the results obtained in (16) the values of Q_i (total flow in month i) for all the calibration basins;

(18) Calculate for each calibration basin the value of K_{ij} using the expression:

$$K_{ij} = \frac{Q_{i\ measj} - Q'_{ij}}{Q'_{ij}}$$

where $Q_{i\ measj}$ is the observed flow of basin j in month i and Q'_{ij} is the estimated flow;

(19) If all absolute values of K_{ij} are less than 0.20 the calculation continues from (25) on. If some absolute values of K_{ij} are larger, then the calculation continues from (20) on;

(20) The values of P_i estimated in (12) are recalculated in each square of the calibration basins using the formula:

$$P_{inewjn} = P_{ioldjn} + \Delta P_i$$

where P_{inewjn} is the new precipitation in square n of basin j, P_{ioldjn} is the last estimated value of precipitation in the same square and ΔPi is the correction in precipitation;

(21) Calculate a new correlation between precipitation and physiographic characteristics using, in addition to the measured precipitation values, the precipitation estimates in each of the squares of the calibration basin. However, the latter estimates are included in the correlation with a lesser weight than the measured precipitation values. The weights are calculated for each calibration basin as $\frac{1}{nj}$ where nj is the number of the squares in basin j;

(22) Estimate using the results obtained in (21) new P_i values in each square of the calibration basins;

(23) Iterate from step 15 on using as precipitation that estimated in (22). If, after 5 iterations, values of K_{ij} do not

converge to values below 0.20, stop calculation and re-examine input data;

(24) If input data appear to be correct, plot values of K and check if these can be regionalized. If this is possible, divide area into two regions: one with basins with positive K's and iterate from (9) on for each region separately;

(25) Estimate precipitation for month i in each square of the river basins included in the validation sample using the last correlation between precipitation and physiographic characteristics;

(26) Estimate the runoff for month i $-\Delta t$ for each square of the river basins included in the validation sample using correlation obtained in (9);

(27) Estimate the temperature for month i for each square of the river basins included in the validation sample using correlation obtained in (13);

(28) Estimate evapotranspiration for month i in each square of the validation basins using the results obtained in (25), (26) and (27);

(29) Estimate runoff for month i in each square of the basins included in the validation basins using the results obtained in (25), (26) and (28);

(30) Estimate total flow for month i for each basin included in the validation sample;

(31) Calculate for each basin included in the validation sample the values K_{ij};

(32) If absolute values of K_{ij} for the basins included in the validation sample are below 0.3 go to (33). Otherwise iterate from (23) on (but reducing absolute values of K_{ij} to less than 0.15);

(33) Repeat calculations for the next month i $+\Delta t$ starting with (11). In these calculations, the last estimates of Q_i are used as estimates of $Q_{i-\Delta t}$;

(34) Compare the last month values of Q_i (i.e. in our case April) to initially calculated values of $Q_{i-\Delta t}$ in step (10). If differences appear to be significant, iterate from (10) on using as estimates of $Q_{i-\Delta t}$ in each square the values of Q_i obtained for the last month;

(35) Iterate from (10) to (24) and from (33) to (34) on using all data (the calibration and validation sample);

(36) Using the final results obtained in (35), produce maps of precipitation, evaporation and runoff for each month.

APPENDIX B

SQUARE GRID PROGRAM

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(D) EXAMPLE - Nova Scotia Pilot Study (OUTPUT)	B-3
(E) Verification Runs	B-32

(A) Working procedure :
==========

1) Prepare following files:
   BRAZMAST.FMT, HGRID0.FMT, HGRIDD.FMT, BRAZINDX.FMT,
   BRAZSTA.AL, BRAZTEMP.FMT, BRAZPREC.FMT, BRAZFLOW.TOT, &
   BRAZIDEN.DAT - see section "C" below for contents of these
   files; the formats are in file "MWBALFIL.DOC" on the PDP11/44.
2) Run MWBAL0
3) Run MWBALFMT
4) Run MWBALA
5) Run MWBAL2 with option 5
6) Run MWBAL1 -- for month i
7) Run MWBAL2 with option 1
8) Run MWBAL3 -- for month i
9) Run MWBAL2 with option 2
10) Run MWBAL4
11) Run MWBAL5
12) Edit file "BRAZSTA.V00", add downstream station manually
13) Run BRAZFGEN
14) Run MWBALR -- for month (i-1)
15) Run MWBAL2 with option 6
16) Run MWBALSTA -- for month i
17) Run MWBALCAL -- for month (i-1)
18) Run MWBAL6 with option T=1,P=1,E=1,R=2
19) Run MWBAL7
20) Run MWBAL6 with option P=2
21) Run MWBAL2 with option 3
22) Run MWBAL6 with option P=1,E=1,R=2
23) Run MWBAL7
24) Is K & R factor improved ? if yes, go to 20
25) Run MWBAL6 with option R=3
26) Run MWBAL2 with option 4
27) Run MWBAL6 with option R=1
28) Run MWBAL7
29) ** Backup the equations :
    BRAZEQTP.DAT, BRAZEQTR.DAT & BRAZEQTT.DAT
30) Run MWBALCPY -- for month i
31) month i = month (i+1)
32) Run MWBAL1 for month i
33) Run MWBAL3 for month i
34) Run MWBAL2 for options 1 & 2
35) Run MWBALSTA for month i
36) go to 18

(B) Programs :
==========

1) MWBAL0 ---- Converts master file to binary format.
2) MWBALFMT -- Converts all index files to direct access format.
3) MWBALA ---- Creates correlation file for "ALPHA" regression analysis.
4) BRAZFGEN -- Computes differential runoff.
5) MWBALR ---- Creates correlation file for "Runoff" regression analysis.
6) MWBAL1 ---- Creates correlation file for "Temperature" regression analysis.
7) MWBAL2 ---- Performs stepwise regression analysis.
8) MWBAL3 ---- Creates correlation file for "Precipitation" regression analysis.
9) MWBAL4 ---- Builds the complete correlation file.
10) MWBAL5 ---- Builds correlation station file.
11) MWBALSTA -- Copies the measured runoff to the working correlation station file.
12) MWBALCAL -- Calculates the alpha, temperature, precipitation and runoff for each square in correlation file.
13) MWBAL6 ---- Evaluates long term hydro-climatic variables either in the correlation file or master file.
14) MWBAL7 ---- Computes K & R factors of total basins from those of differential basins.
15) MWBALCPY -- Copies the long term hydro-climatic variables to permenant locations.

(C) Files :
==========

1) BRAZMAST.FMT -- Master file containing physiographic data set.
2) HGRID0.FMT ---- Hydrologic grid file, each element represents a square grid of the gauged drainages (total area).
3) HGRIDD.FMT ---- Hydrologic grid file, each element represents a square grid of the gauged drainages (differential area).
4) BRAZINDX.FMT -- Index to the master file, each square of interest in the matrix is assigned a unique record # acting as a pointer to the master file.
5) BRAZSTA.AL ---- ALPHA value file.
6) BRAZTEMP.FMT -- Mean monthly temperature data file for the MET station grids.
7) BRAZPREC.FMT -- Mean monthly precipitation data file for the MET station grids.
8) BRAZFLOW.TOT -- Mean monthly runoff data file for the hydrometric station grids.
9) BRAZIDEN.DAT -- Labels of all independent variables used in the regression program.

(D) EXAMPLE - Nova Scotia Pilot Study (OUTPUT) : (pg. B-3 to B-31)

```
$>R MWBAL0

CONVERT MASTER FILE TO BINARY---
   100
   200
   300
   400
   500
   600
   700
TOTAL # OF RECORDS FORMATTED =     765
NORMAL TERMINATION
TT10  --  STOP

$>
$>
$>R MWBALFMT

CONVERT HGRID0.FMT  ...
HGRID0.FMT CONVERTED, # RECORDS=     756

CONVERT HGRIDD.FMT  ...
HGRID0.FMT CONVERTED, # RECORDS=     756

CONVERT INDEX.FMT  ...
INDEX.FMT CONVERTED, # RECORDS=    4563
$>
$>
$>R MWBALA
ENTER 0----TOTAL AREA, 1---- DIFFERENTIAL ?
0
   100       1  OF       8  -      58  (     232)     544
   200       2  OF       8  -      21  (      84)    1277
   300       3  OF       8  -       8  (      32)     405
   400       4  OF       8  -      38  (     152)    1179
   500       5  OF       8  -      91  (     364)     418
   600       6  OF       8  -     111  (     444)     365
   700       7  OF       8  -     393  (    1572)     679
   800       8  OF       8  -      35  (     140)     868
$>
$>
$>R MWBAL2
TYPE? (1-INIT TEMP,2-INIT PREC,3-INTER PREC,4-RUNOFF)
      (5-ALPHA, 6-INIT RUNOFF)
5
ENTER # OF INDEPENDENT VARIABLES ?
3
ENTER INDEPENDENT VARIABLE #       1 ?
2
ENTER INDEPENDENT VARIABLE #       2 ?
20
ENTER INDEPENDENT VARIABLE #       3 ?
21
PCT (0 TO INCLUED ALL VARIABLES) ?
.04
# PROBLEM ?
1
DEP. VARIABLE DESCRIPTION ?
ALPHA
TT10  --  STOP
```

```
@)T PRINTER.DAT


STEP-WISE MULTIPLE REGRESSION.....#    1     ALPHA

NUMBER OF OBSERVATIONS     8

NUMBER OF VARIABLES        4

CONSTANT TO LIMIT VARIABLES  0.04000

VARIABLE      MEAN      STANDARD
  NO.                   DEVIATION
    1        29.375       6.653     ROW NUMBER
    2         6.375       6.140     SWAMP AREA X100
    3        10.250       3.991     FRESH H2O AREA X100
    4       716.875     356.945     ALPHA


STEP-WISE MULTIPLE REGRESSION.....#    1     ALPHA



STEPWISE MULTIPLE REGRESSION.....#    1ALPHA

DEPENDANT VARIABLE.............  4
NUMBER OF VARIABLESFORCED....  0
NUMBER OF VARIABLES DELETED...  0


STEP  1
-------
VARIABLE ENTERED....  2

SUM OF SQUARES REDUCED IN THIS STEP....  0.4017635E+06
PROPORTION REDUCED IN THIS STEP.......  0.4504747E+00

CUMULATIVE SUM OF SQUARES REDUCED.....  0.4017635E+06
CUMULATIVE PROPORTION REDUCED.........  0.4504747E+00  OF  0.8918669E+06

FOR  1 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.6711741E+00
      (ADJUSTED FOR D.F.)...........  0.6711741E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.4918515E+01
  STANDARD ERROR OF ESTIMATE.......  0.2858040E+03
      (ADJUSTED FOR D.F.)...........  0.2858040E+03

VARIABLE     REGRESSION     STD. ERROR OF      COMPUTED
 NUMBER      COEFFICIENT     REG. COEFF.       T-VALUE

    2       0.390199E+02    0.175942E+02   0.221777E+01     SWAMP AREA X100

INTERCEPT   0.468123E+03


STEP-WISE MULTIPLE REGRESSION.....#    1     ALPHA

                  TABLE OF RESIDUALS
STATION     Y VALUE      Y ESTIMATE      RESIDUAL    PERCENT
   100       544.00          585.18        -41.18      -7.6
   200      1277.00         1248.52         28.48       2.2
   300       405.00          507.14       -102.14     -25.2
   400      1179.00          780.28        398.72      33.8
   500       418.00          624.20       -206.20     -49.3
   600       365.00          741.26       -376.26    -103.1
   700       679.00          741.26        -62.26      -9.2
   800       868.00          507.14        360.86      41.6
```

```
$>R MWBAL1
ENTER MONTH (1-12) ?
5

  10 RECORDS IN BRAZTEMP
TT10  --  STOP

$>
$>
$>R MWBAL2
TYPE? (1-INIT TEMP,2-INIT PREC,3-INTER PREC,4-RUNOFF)
      (5-ALPHA, 6-INIT RUNOFF)
1
ENTER # OF INDEPENDENT VARIABLES ?
3
ENTER INDEPENDENT VARIABLE #      1 ?
1
ENTER INDEPENDENT VARIABLE #      2 ?
9
ENTER INDEPENDENT VARIABLE #      3 ?
22
PCT (0 TO INCLUED ALL VARIABLES) ?
.04
# PROBLEM ?
2
DEP. VARIABLE DESCRIPTION ?
INIT TEMP (MAY)
TT10  --  STOP
```

```
A>T PRINTER.DAT

STEP-WISE MULTIPLE REGRESSION.....#    2     INIT TEMP (MAY)

NUMBER OF OBSERVATIONS     9

NUMBER OF VARIABLES        4

CONSTANT TO LIMIT VARIABLES  0.04000

VARIABLE      MEAN      STANDARD
  NO.                   DEVIATION
    1         48.111      28.707     COLUMN NUMBER
    2        194.444     122.970     ELEVATION (NE)
    3         20.000      41.037     SEA AREA X100
    4          8.222       0.972     INIT TEMP (MAY)


STEP-WISE MULTIPLE REGRESSION.....#    2     INIT TEMP (MAY)

STEPWISE MULTIPLE REGRESSION.....#    2INIT TEMP (MAY)

DEPENDANT VARIABLE.............  4
NUMBER OF VARIABLESFORCED....  0
NUMBER OF VARIABLES DELETED...  0


STEP  1
-------
VARIABLE ENTERED....  1

SUM OF SQUARES REDUCED IN THIS STEP....  0.3243031E+01
PROPORTION REDUCED IN THIS STEP........  0.4292246E+00

CUMULATIVE SUM OF SQUARES REDUCED......  0.3243031E+01
CUMULATIVE PROPORTION REDUCED..........  0.4292246E+00  OF  0.7555556E+01

FOR  1 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.6551524E+00
       (ADJUSTED FOR D.F.)...........  0.6551524E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.5264019E+01
  STANDARD ERROR OF ESTIMATE.........  0.7849045E+00
       (ADJUSTED FOR D.F.)...........  0.7849045E+00

VARIABLE      REGRESSION      STD. ERROR OF      COMPUTED
 NUMBER       COEFFICIENT      REG. COEFF.       T-VALUE

    1       -0.221788E-01     0.966672E-02   -0.229434E+01     COLUMN NUMBER

INTERCEPT    0.928927E+01


STEPWISE MULTIPLE REGRESSION.....#    2INIT TEMP (MAY)
STEP  2
-------
VARIABLE ENTERED....  3

SUM OF SQUARES REDUCED IN THIS STEP....  0.6335245E+00
PROPORTION REDUCED IN THIS STEP........  0.8384883E-01

CUMULATIVE SUM OF SQUARES REDUCED......  0.3876555E+01
CUMULATIVE PROPORTION REDUCED..........  0.5130734E+00  OF  0.7555556E+01

FOR  2 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.7162914E+00
       (ADJUSTED FOR D.F.)...........  0.6659673E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.3161093E+01
  STANDARD ERROR OF ESTIMATE.........  0.7830497E+00
       (ADJUSTED FOR D.F.)...........  0.8371153E+00

VARIABLE      REGRESSION      STD. ERROR OF      COMPUTED
 NUMBER       COEFFICIENT      REG. COEFF.       T-VALUE

    1       -0.259092E-01     0.103186E-01   -0.251093E+01     COLUMN NUMBER

    3        0.733728E-02     0.721843E-02    0.101646E+01     SEA AREA X100

INTERCEPT    0.932200E+01


STEP-WISE MULTIPLE REGRESSION.....#    2     INIT TEMP (MAY)

                  TABLE OF RESIDUALS
STATION      Y VALUE       Y ESTIMATE        RESIDUAL    PERCENT
  1000          8.00             7.46            0.54        6.8
  2000          9.00             8.49            0.51        5.6
  3000          9.00             9.35           -0.35       -3.9
  4000          8.00             7.56            0.44        5.5
  5000          6.00             7.64           -1.64      -27.4
  6000          8.00             7.97            0.03        0.3
  7000          8.00             7.76            0.24        3.0
  8000          9.00             9.01           -0.01       -0.1
  9000          9.00             8.75            0.25        2.8
```

```
$>R MWBAL3
ENTER MONTH (1-12) ?

5

  10 RECORDS IN BRAZPREC
TT10  --  STOP

$>
$>
$>R MWBAL2
TYPE? (1-INIT TEMP,2-INIT PREC,3-INTER PREC,4-RUNOFF)
      (5-ALPHA, 6-INIT RUNOFF)
2
ENTER # OF INDEPENDENT VARIABLES ?
3
ENTER INDEPENDENT VARIABLE #      1 ?
2
ENTER INDEPENDENT VARIABLE #      2 ?
18
ENTER INDEPENDENT VARIABLE #      3 ?
19
PCT (0 TO INCLUED ALL VARIABLES) ?
.04
# PROBLEM ?
3
DEP. VARIABLE DESCRIPTION ?
INIT PREC (MAY)
TT10  --  STOP
```

```
0>T PRINTER.DAT

STEP-WISE MULTIPLE REGRESSION.....#    3     INIT PREC (MAY)

NUMBER OF OBSERVATIONS     9

NUMBER OF VARIABLES        4

CONSTANT TO LIMIT VARIABLES  0.04000

VARIABLE     MEAN      STANDARD
  NO.                 DEVIATION
   1         24.111      14.521     ROW NUMBER
   2        208.222     120.592     WOODED AREA X100
   3        158.889     122.316     BARREN AREA X100
   4        109.444      16.272     INIT PREC (MAY)


STEP-WISE MULTIPLE REGRESSION.....#    3     INIT PREC (MAY)

STEPWISE MULTIPLE REGRESSION.....#    3INIT PREC (MAY)

DEPENDANT VARIABLE.............  4
NUMBER OF VARIABLESFORCED....  0
NUMBER OF VARIABLES DELETED...  0


STEP  1
-------
VARIABLE ENTERED....  2

SUM OF SQUARES REDUCED IN THIS STEP....  0.1543208E+04
PROPORTION REDUCED IN THIS STEP.......  0.7285395E+00

CUMULATIVE SUM OF SQUARES REDUCED.....  0.1543208E+04
CUMULATIVE PROPORTION REDUCED.........  0.7285395E+00  OF  0.2118222E+04

FOR  1 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.8535452E+00
      (ADJUSTED FOR D.F.)...........  0.8535452E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.1878644E+02
  STANDARD ERROR OF ESTIMATE.......  0.9063377E+01
      (ADJUSTED FOR D.F.)...........  0.9063377E+01

VARIABLE     REGRESSION      STD. ERROR OF      COMPUTED
 NUMBER      COEFFICIENT      REG. COEFF.       T-VALUE

   2        0.115172E+00     0.265721E-01    0.433433E+01     WOODED AREA X100

INTERCEPT   0.854630E+02


STEPWISE MULTIPLE REGRESSION.....#    3INIT PREC (MAY)
STEP  2
-------
VARIABLE ENTERED....  1

SUM OF SQUARES REDUCED IN THIS STEP....  0.4162743E+03
PROPORTION REDUCED IN THIS STEP.......  0.1965206E+00

CUMULATIVE SUM OF SQUARES REDUCED.....  0.1959483E+04
CUMULATIVE PROPORTION REDUCED.........  0.9250601E+00  OF  0.2118222E+04

FOR  2 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.9618005E+00
      (ADJUSTED FOR D.F.)...........  0.9562188E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.3703207E+02
  STANDARD ERROR OF ESTIMATE.......  0.5143594E+01
      (ADJUSTED FOR D.F.)...........  0.5498734E+01

VARIABLE     REGRESSION      STD. ERROR OF      COMPUTED
 NUMBER      COEFFICIENT      REG. COEFF.       T-VALUE

   2        0.865412E-01     0.167185E-01    0.517637E+01     WOODED AREA X100

   1       -0.550732E+00     0.138841E+00   -0.396664E+01     ROW NUMBER

INTERCEPT   0.104703E+03


STEP-WISE MULTIPLE REGRESSION.....#    3     INIT PREC (MAY)

                    TABLE OF RESIDUALS
STATION     Y VALUE       Y ESTIMATE       RESIDUAL    PERCENT
  1000        121.00          121.38          -0.38      -0.3
  2000         97.00          104.47          -7.47      -7.7
  3000         94.00           96.28          -2.28      -2.4
  4000         99.00          103.51          -4.51      -4.6
  5000        128.00          129.80          -1.80      -1.4
  6000        136.00          131.45           4.55       3.3
  7000        101.00           95.23           5.77       5.7
  8000        117.00          114.76           2.24       1.9
  9000         92.00           88.12           3.88       4.2
```

```
$>R MWBAL4

BUILDING THE CORRELATION FILE: -- # OF PREC REC=  10
# OF PRECIPITATION RECORDS =     10

BUILDING RUNOFF CORRELATION PART :---
TOTAL # OF RECORDS=    765
$>
$>
$>R MWBAL5
   100      12      69   232.0000
   200      70      90   84.00000
   300      91      98   32.00000
   400      99     136   152.0000
   500     137     227   364.0000
   600     228     338   444.0000
   700     339     731   1572.000
   800     732     766   140.0000
$>
$>
$>TYPE BRAZSTA.V00
     9
  100     12     69   999.   999.    232. 1.00      0      0.000
  200     70     90   999.   999.     84. 1.00      0      0.000
  300     91     98   999.   999.     32. 1.00      0      0.000
  400     99    136   999.   999.    152. 1.00      0      0.000
  500    137    227   999.   999.    364. 1.00      0      0.000
  600    228    338   999.   999.    444. 1.00      0      0.000
  700    339    731   999.   999.   1572. 1.00      0      0.000
  800    732    766   999.   999.    140. 1.00      0      0.000
$>
$>
$>R BRAZFGEN
   100   141.0000
   200   173.0000
   300   118.0000
   400   132.0000
   500   123.0000
   600   171.0000
   700   148.0000
   800   143.0000
STNA & AREA & DOWN      100    232.0000          0
STNA & AREA & DOWN      200    84.00000          0
STNA & AREA & DOWN      300    32.00000          0
STNA & AREA & DOWN      400    152.0000          0
STNA & AREA & DOWN      500    364.0000          0
STNA & AREA & DOWN      600    444.0000          0
STNA & AREA & DOWN      700    1572.000          0
STNA & AREA & DOWN      800    140.0000          0
PROCESSING COMPLETED
TT10  --  STOP
```

```
$>R MWBALR
ENTER MONTH (1-12) ?
4
STATION      1  OF      8   -------     58  (    232)
STATION      2  OF      8   -------     21  (     84)
STATION      3  OF      8   -------      8  (     32)
STATION      4  OF      8   -------     38  (    152)
STATION      5  OF      8   -------     91  (    364)
STATION      6  OF      8   -------    111  (    444)
STATION      7  OF      8   -------    393  (   1572)
STATION      8  OF      8   -------     35  (    140)
TT10  --  STOP

$>
$>
$>R MWBAL2
TYPE? (1-INIT TEMP,2-INIT PREC,3-INTER PREC,4-RUNOFF)
      (5-ALPHA, 6-INIT RUNOFF)
6
ENTER # OF INDEPENDENT VARIABLES ?
3
ENTER INDEPENDENT VARIABLE #      1 ?
2
ENTER INDEPENDENT VARIABLE #      2 ?
19
ENTER INDEPENDENT VARIABLE #      3 ?
21
PCT (0 TO INCLUED ALL VARIABLES) ?
.04
# PROBLEM ?
4
DEP. VARIABLE DESCRIPTION ?
INIT RUNOFF (APRIL)
TT10  --  STOP
```

```
&)T PRINTER.DAT
STEP-WISE MULTIPLE REGRESSION.....0    4     INIT RUNOFF (APRIL)

NUMBER OF OBSERVATIONS      8

NUMBER OF VARIABLES         4

CONSTANT TO LIMIT VARIABLES  0.04000

VARIABLE      MEAN      STANDARD
  NO.                   DEVIATION
   1         29.375        6.653     ROW NUMBER
   2         16.125       20.767     BARREN AREA X100
   3         10.250        3.991     FRESH H2O AREA X100
   4        151.000       19.640     INIT RUNOFF (APRIL)


STEP-WISE MULTIPLE REGRESSION.....0    4     INIT RUNOFF (APRIL)


STEPWISE MULTIPLE REGRESSION.....0    4INIT RUNOFF (APRIL)

DEPENDANT VARIABLE.............  4
NUMBER OF VARIABLESFORCED....   0
NUMBER OF VARIABLES DELETED...  0


STEP  1
-------
VARIABLE ENTERED....  3

SUM OF SQUARES REDUCED IN THIS STEP....  0.1111247E+04
PROPORTION REDUCED IN THIS STEP .......  0.4115728E+00

CUMULATIVE SUM OF SQUARES REDUCED......  0.1111247E+04
CUMULATIVE PROPORTION REDUCED..........  0.4115728E+00  OF  0.2700000E+04

FOR  1 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.6415394E+00
       (ADJUSTED FOR D.F.)...........  0.6415393E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.4196673E+01
  STANDARD ERROR OF ESTIMATE.........  0.1627244E+02
       (ADJUSTED FOR D.F.)...........  0.1627244E+02

 VARIABLE     REGRESSION      STD. ERROR OF      COMPUTED
  NUMBER      COEFFICIENT      REG. COEFF.       T-VALUE

    3       -0.315695E+01     0.154104E+01   -0.204858E+01     FRESH H2O AREA X100
00
 INTERCEPT    0.183359E+03


STEPWISE MULTIPLE REGRESSION.....0    4INIT RUNOFF (APRIL)
STEP  2
-------
VARIABLE ENTERED....  2

SUM OF SQUARES REDUCED IN THIS STEP....  0.3962873E+03
PROPORTION REDUCED IN THIS STEP........  0.1467731E+00

CUMULATIVE SUM OF SQUARES REDUCED......  0.1507534E+04
CUMULATIVE PROPORTION REDUCED..........  0.5583459E+00  OF  0.2700000E+04

FOR  2 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.7472255E+00
       (ADJUSTED FOR D.F.)...........  0.6962305E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.3160538E+01
  STANDARD ERROR OF ESTIMATE.........  0.1544322E+02
       (ADJUSTED FOR D.F.)...........  0.1668059E+02

 VARIABLE     REGRESSION      STD. ERROR OF      COMPUTED
  NUMBER      COEFFICIENT      REG. COEFF.       T-VALUE

    3       -0.463025E+01     0.185614E+01   -0.249455E+01     FRESH H2O AREA X100
00
    2       -0.459826E+00     0.356719E+00   -0.128904E+01     BARREN AREA X100

 INTERCEPT    0.205875E+03


STEP-WISE MULTIPLE REGRESSION.....0    4     INIT RUNOFF (APRIL)

                    TABLE OF RESIDUALS
STATION     Y VALUE      Y ESTIMATE      RESIDUAL     PERCENT
  100        131.00         156.35         -25.35       -19.4
  200        176.00         168.83           7.17         4.1
  300        126.00         122.53           3.47         2.8
  400        143.00         150.34          -7.34        -5.1
  500        159.00         143.38          15.62         9.8
  600        180.00         167.09          12.91         7.2
  700        151.00         153.59          -2.59        -1.7
  800        142.00         145.87          -3.87        -2.7
```

```
$>R MWBALSTA
MONTH (1-12) ?
5
$>
$>
$>T BRAZSTA.DAT
    9     5 ---- MONTH  5
  100    12    69 100.00 999.00    232. 1.00      0
  200    70    90 131.00 999.00     84. 1.00      0
  300    91    98 107.00 999.00     32. 1.00      0
  400    99   136 116.00 999.00    152. 1.00      0
  500   137   227 132.00 999.00    364. 1.00      0
  600   228   338 145.00 999.00    444. 1.00      0
  700   339   731 126.00 999.00   1572. 1.00      0
  800   732   766 105.00 999.00    140. 1.00      0
$>
$>
$>R MWBALCAL
ENTER MONTH ?
4
    1 FILE :BRAZEQTA.DAT
    5 FILE :BRAZEQTT.DAT
   17 FILE :BRAZEQTP.DAT
   29 FILE :BRAZEQTR.DAT


RECORD   100     ALPHA  1873
    0    0    0     8    0    0    0    0    0    0    0    0
    0    0    0   124    0    0    0    0    0    0    0    0
    0    0    0   206    0    0    0    0    0    0    0    0
RECORD   200     ALPHA   468
    0    0    0     8    0    0    0    0    0    0    0    0
    0    0    0   122    0    0    0    0    0    0    0    0
    0    0    0   113    0    0    0    0    0    0    0    0
RECORD   300     ALPHA   468
    0    0    0     9    0    0    0    0    0    0    0    0
    0    0    0   120    0    0    0    0    0    0    0    0
    0    0    0   189    0    0    0    0    0    0    0    0
RECORD   400     ALPHA   468
    0    0    0     8    0    0    0    0    0    0    0    0
    0    0    0   119    0    0    0    0    0    0    0    0
    0    0    0   169    0    0    0    0    0    0    0    0
   RECORD      500 OF     765
RECORD   500     ALPHA   468
    0    0    0     8    0    0    0    0    0    0    0    0
    0    0    0   114    0    0    0    0    0    0    0    0
    0    0    0   178    0    0    0    0    0    0    0    0
RECORD   600     ALPHA   468
    0    0    0     8    0    0    0    0    0    0    0    0
    0    0    0   120    0    0    0    0    0    0    0    0
    0    0    0   202    0    0    0    0    0    0    0    0
RECORD   700     ALPHA   936
    0    0    0     8    0    0    0    0    0    0    0    0
    0    0    0   124    0    0    0    0    0    0    0    0
    0    0    0   113    0    0    0    0    0    0    0    0
```

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
4

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
T=1
VARIABLE ?
P=1
VARIABLE ?
E=1
VARIABLE ?
R=2
# OF STATIONS :       9
**** ALLOWABLE PRECIPITATION RANGE :   1.000000       223.3484
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
```

```
$>R MWBAL7
$>
$>
$>T PRINTER.DAT

   K AND R -FACTORS-              MONTH  5
   ----------------------------------------
   DIFFERENTIAL AREAS

          -RUNOFF-                    K         R
STATION  REC.   EST.    AREA       FACTOR    FACTOR
         (MM)   (MM)  (SQ.KM)
   100 100.00  53.67     232.      0.86      1.43
   200 131.00  45.57      84.      1.87      2.32
   300 107.00  59.00      32.      0.81      1.37
   400 116.00  48.68     152.      1.38      1.83
   500 132.00  51.15     364.      1.58      1.79
   600 145.00  51.56     444.      1.81      2.06
   700 126.00  50.34    1572.      1.50      1.85
   800 105.00  54.89     140.      0.91      1.41

   K AND R -FACTORS-              MONTH  5
   ----------------------------------------
   TOTAL AREAS

          -RUNOFF-                    K         R
STATION  REC.   EST.    AREA       FACTOR    FACTOR
         (MM)   (MM)  (SQ.KM)
   100 100.00  53.67     232.      0.86      1.43
   200 131.00  45.57      84.      1.87      2.32
   300 107.00  59.00      32.      0.81      1.37
   400 116.00  48.68     152.      1.38      1.83
   500 132.00  51.15     364.      1.58      1.79
   600 145.00  51.56     444.      1.81      2.06
   700 126.00  50.34    1572.      1.50      1.85
   800 105.00  54.89     140.      0.91      1.41
```

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
1

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
P=2
# OF STATIONS :       9
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
$>
$>
$>R MWBAL2
TYPE? (1-INIT TEMP,2-INIT PREC,3-INTER PREC,4-RUNOFF)
      (5-ALPHA, 6-INIT RUNOFF)
3
PCT (0 TO INCLUED ALL VARIABLES) ?
.04
# PROBLEM ?
5
DEP. VARIABLE DESCRIPTION ?
INTER PREC (MAY)
TT10  --  STOP
```

```
0>T PRINTER.DAT
STEP-WISE MULTIPLE REGRESSION.....0    5     INTER PREC (MAY)

NUMBER OF OBSERVATIONS   755

NUMBER OF VARIABLES       12

CONSTANT TO LIMIT VARIABLES  0.04000

VARIABLE      MEAN      STANDARD
  NO.                   DEVIATION
    1         51.438      22.928     COLUMN NUMBER
    2         30.703       9.894     ROW NUMBER
    3        452.695     180.662     ELEVATION (NW)
    4        459.238     186.470     ELEVATION (SW)
    5        463.377     304.194     ELEVATION (SE)
    6        445.669     184.720     ELEVATION (NE)
    7        367.960      39.621     WOODED AREA X100
    8         15.992      33.629     BARREN AREA X100
    9          6.538      16.954     SWAMP AREA X100
   10          9.282      18.536     FRESH H2O AREA X100
   11          0.132       3.639     SEA AREA X100
   12        218.083      24.797     INTER PREC



STEP-WISE MULTIPLE REGRESSION.....0    5     INTER PREC (MAY)

STEPWISE MULTIPLE REGRESSION.....0    5INTER PREC (MAY)

DEPENDANT VARIABLE..... 12
NUMBER OF VARIABLESFORCED....  0
NUMBER OF VARIABLES DELETED...  0


STEP  1
-------
VARIABLE ENTERED....  8

SUM OF SQUARES REDUCED IN THIS STEP....  0.4589639E+05
PROPORTION REDUCED IN THIS STEP.......  0.9899115E-01

CUMULATIVE SUM OF SQUARES REDUCED.....  0.4589639E+05
CUMULATIVE PROPORTION REDUCED.........  0.9899115E-01  OF  0.4636414E+06

FOR  1 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.3146286E+00
      (ADJUSTED FOR D.F.)...........  0.3146286E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.8272985E+02
  STANDARD ERROR OF ESTIMATE.......  0.2355365E+02
      (ADJUSTED FOR D.F.)...........  0.2355365E+02

VARIABLE      REGRESSION      STD. ERROR OF      COMPUTED
 NUMBER       COEFFICIENT      REG. COEFF.       T-VALUE

    8       -0.232001E+00     0.255070E-01   -0.909560E+01     BARREN AREA X100

INTERCEPT    0.221794E+03



STEPWISE MULTIPLE REGRESSION.....0    5INTER PREC (MAY)
STEP  2
-------
VARIABLE ENTERED....  2

SUM OF SQUARES REDUCED IN THIS STEP....  0.2355175E+05
PROPORTION REDUCED IN THIS STEP.......  0.5079735E-01

CUMULATIVE SUM OF SQUARES REDUCED.....  0.6944814E+05
CUMULATIVE PROPORTION REDUCED.........  0.1497885E+00  OF  0.4636414E+06

FOR  2 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.3870252E+00
      (ADJUSTED FOR D.F.)...........  0.3855638E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.6624289E+02
  STANDARD ERROR OF ESTIMATE.......  0.2289527E+02
      (ADJUSTED FOR D.F.)...........  0.2291046E+02

VARIABLE      REGRESSION      STD. ERROR OF      COMPUTED
 NUMBER       COEFFICIENT      REG. COEFF.       T-VALUE

    8       -0.184507E+00     0.257866E-01   -0.715516E+01     BARREN AREA X100

    2       -0.587493E+00     0.876469E-01   -0.670295E+01     ROW NUMBER

INTERCEPT    0.239072E+03
```

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
3

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
P=1
VARIABLE ?
E=1
VARIABLE ?
R=2
# OF STATIONS :       9
**** ALLOWABLE PRECIPITATION RANGE :   44.50200       391.6649
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
```

```
$>R MWBAL7
$>
$>
$>T PRINTER.DAT

   K AND R -FACTORS-              MONTH  5
   ----------------------------------------
   DIFFERENTIAL AREAS

          -RUNOFF-                    K        R
STATION  REC.   EST.    AREA        FACTOR   FACTOR
         (MM)   (MM)   (SQ.KM)
   100 100.00  82.33      232.      0.21     1.12
   200 131.00  69.71       84.      0.88     1.67
   300 107.00  91.13       32.      0.17     1.09
   400 116.00  74.53      152.      0.56     1.37
   500 132.00  79.26      364.      0.67     1.38
   600 145.00  77.67      444.      0.87     1.56
   700 126.00  76.85     1572.      0.64     1.41
   800 105.00  84.51      140.      0.24     1.12

   K AND R -FACTORS-              MONTH  5
   ----------------------------------------
   TOTAL AREAS

          -RUNOFF-                    K        R
STATION  REC.   EST.    AREA        FACTOR   FACTOR
         (MM)   (MM)   (SQ.KM)
   100 100.00  82.33      232.      0.21     1.12
   200 131.00  69.71       84.      0.88     1.67
   300 107.00  91.13       32.      0.17     1.09
   400 116.00  74.53      152.      0.56     1.37
   500 132.00  79.26      364.      0.67     1.38
   600 145.00  77.67      444.      0.87     1.56
   700 126.00  76.85     1572.      0.64     1.41
   800 105.00  84.51      140.      0.24     1.12
```

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
1

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
P=2
# OF STATIONS :       9
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
$>
$>
$>R MWBAL2
TYPE? (1-INIT TEMP,2-INIT PREC,3-INTER PREC,4-RUNOFF)
      (5-ALPHA, 6-INIT RUNOFF)
3
PCT (0 TO INCLUED ALL VARIABLES) ?
.04
# PROBLEM ?
55
DEP. VARIABLE DESCRIPTION ?
INTER PREC (MAY)
TT10  --  STOP
```

[redacted].DAT

STEP-WISE MULTIPLE REGRESSION.....# 55 INTER PREC (MAY)

NUMBER OF OBSERVATIONS 755

NUMBER OF VARIABLES 12

CONSTANT TO LIMIT VARIABLES 0.04000

VARIABLE NO.	MEAN	STANDARD DEVIATION	
1	51.438	22.928	COLUMN NUMBER
2	30.703	9.894	ROW NUMBER
3	452.695	180.662	ELEVATION (NW)
4	459.238	186.470	ELEVATION (SW)
5	463.377	304.194	ELEVATION (SE)
6	445.669	184.720	ELEVATION (NE)
7	367.960	39.621	WOODED AREA X100
8	15.992	33.629	BARREN AREA X100
9	6.538	16.954	SWAMP AREA X100
10	9.282	18.536	FRESH H2O AREA X100
11	0.132	3.639	SEA AREA X100
12	303.538	29.957	INTER PREC (MAY)

STEP-WISE MULTIPLE REGRESSION.....# 55 INTER PREC (MAY)

STEPWISE MULTIPLE REGRESSION.....# 55INTER PREC (MAY)

DEPENDANT VARIABLE..... 12
NUMBER OF VARIABLESFORCED.... 0
NUMBER OF VARIABLES DELETED... 0

STEP 1

VARIABLE ENTERED.... 8

SUM OF SQUARES REDUCED IN THIS STEP.... 0.8855955E+05
PROPORTION REDUCED IN THIS STEP..... 0.1308758E+00

CUMULATIVE SUM OF SQUARES REDUCED..... 0.8855955E+05
CUMULATIVE PROPORTION REDUCED..... 0.1308758E+00 OF 0.6766685E+06

FOR 1 VARIABLES ENTERED
MULTIPLE CORRELATION COEFFICIENT... 0.3617676E+00
(ADJUSTED FOR D.F.)..... 0.3617676E+00
F-VALUE FOR ANALYSIS OF VARIANCE... 0.1133894E+03
STANDARD ERROR OF ESTIMATE..... 0.2794676E+02
(ADJUSTED FOR D.F.)..... 0.2794676E+02

VARIABLE NUMBER	REGRESSION COEFFICIENT	STD. ERROR OF REG. COEFF.	COMPUTED T-VALUE	
8	-0.322269E+00	0.302645E-01	-0.106484E+02	BARREN AREA X100
INTERCEPT	0.308691E+03			

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
3

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
P=1
VARIABLE ?
E=1
VARIABLE ?
R=2
# OF STATIONS :       9
**** ALLOWABLE PRECIPITATION RANGE :   93.83680       513.2387
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
```

```
$>R MWBAL7
$>
$>
$>T PRINTER.DAT

   K AND R -FACTORS-              MONTH  5
   ----------------------------------------
   DIFFERENTIAL AREAS

          -RUNOFF-                    K        R
STATION  REC.   EST.    AREA        FACTOR   FACTOR
         (MM)   (MM)   (SQ.KM)
   100 100.00 107.34      232.     -0.07     0.96
   200 131.00  90.43       84.      0.45     1.36
   300 107.00 118.38       32.     -0.10     0.94
   400 116.00  96.79      152.      0.20     1.14
   500 132.00 102.01      364.      0.29     1.18
   600 145.00 101.67      444.      0.43     1.30
   700 126.00 100.36     1572.      0.26     1.18
   800 105.00 110.89      140.     -0.05     0.97

   K AND R -FACTORS-              MONTH  5
   ----------------------------------------
   TOTAL AREAS

          -RUNOFF-                    K        R
STATION  REC.   EST.    AREA        FACTOR   FACTOR
         (MM)   (MM)   (SQ.KM)
   100 100.00 107.34      232.     -0.07     0.96
   200 131.00  90.43       84.      0.45     1.36
   300 107.00 118.38       32.     -0.10     0.94
   400 116.00  96.79      152.      0.20     1.14
   500 132.00 102.01      364.      0.29     1.18
   600 145.00 101.67      444.      0.43     1.30
   700 126.00 100.36     1572.      0.26     1.18
   800 105.00 110.89      140.     -0.05     0.97
```

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
1

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
P=2
# OF STATIONS :       9
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
$>
$>
$>R MWBAL2
TYPE? (1-INIT TEMP,2-INIT PREC,3-INTER PREC,4-RUNOFF)
      (5-ALPHA, 6-INIT RUNOFF)
3
PCT (0 TO INCLUED ALL VARIABLES) ?
.04
# PROBLEM ?
555
DEP. VARIABLE DESCRIPTION ?
INTER PREC (MAY)
TT10  --  STOP
```

A:\ PRINTER.DAT

```
STEP-WISE MULTIPLE REGRESSION.....@  555     INTER PREC (MAY)

NUMBER OF OBSERVATIONS   755

NUMBER OF VARIABLES       12

CONSTANT TO LIMIT VARIABLES  0.04000

VARIABLE      MEAN      STANDARD
  NO.                   DEVIATION
    1        51.438       22.928     COLUMN NUMBER
    2        30.703        9.894     ROW NUMBER
    3       452.695      180.662     ELEVATION (NW)
    4       459.238      186.470     ELEVATION (SW)
    5       463.377      304.194     ELEVATION (SE)
    6       445.669      184.720     ELEVATION (NE)
    7       367.960       39.621     WOODED AREA X100
    8        15.992       33.629     BARREN AREA X100
    9         6.538       16.954     SWAMP AREA X100
   10         9.282       18.536     FRESH H2O AREA X100
   11         0.132        3.639     SEA AREA X100
   12       355.232       31.882     INTER PREC (MAY)


STEP-WISE MULTIPLE REGRESSION.....@  555     INTER PREC (MAY)



STEPWISE MULTIPLE REGRESSION.....@  555INTER PREC (MAY)

DEPENDANT VARIABLE..... 12
NUMBER OF VARIABLESFORCED....  0
NUMBER OF VARIABLES DELETED...  0


STEP  1
-------
VARIABLE ENTERED....  8

SUM OF SQUARES REDUCED IN THIS STEP....  0.1195530E+06
PROPORTION REDUCED IN THIS STEP.....  0.1559890E+00

CUMULATIVE SUM OF SQUARES REDUCED.....  0.1195530E+06
CUMULATIVE PROPORTION REDUCED.....  0.1559890E+00  OF  0.7664193E+06

FOR  1 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.3949545E+00
      (ADJUSTED FOR D.F.).....  0.3949545E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.1391685E+03
  STANDARD ERROR OF ESTIMATE.....  0.2930959E+02
      (ADJUSTED FOR D.F.).....  0.2930959E+02

VARIABLE     REGRESSION     STD. ERROR OF      COMPUTED
 NUMBER      COEFFICIENT     REG. COEFF.       T-VALUE

    8       -0.374439E+00     0.317403E-01   -0.117970E+02     BARREN AREA X100

INTERCEPT    0.361220E+03
```

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
3

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
P=1
VARIABLE ?
E=1
VARIABLE ?
R=2
# OF STATIONS :       9
**** ALLOWABLE PRECIPITATION RANGE :   132.0568       578.4068
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
```

```
$>R MWBAL7
$>
$>
$>T PRINTER.DAT

   K AND R -FACTORS-              MONTH  5
   ----------------------------------------
   DIFFERENTIAL AREAS

          -RUNOFF-                    K        R
STATION  REC.   EST.    AREA        FACTOR   FACTOR
         (MM)   (MM)   (SQ.KM)
   100 100.00 122.57      232.     -0.18     0.88
   200 131.00 103.24       84.      0.27     1.22
   300 107.00 135.63       32.     -0.21     0.87
   400 116.00 110.55      152.      0.05     1.04
   500 132.00 116.79      364.      0.13     1.09
   600 145.00 115.80      444.      0.25     1.18
   700 126.00 114.51     1572.      0.10     1.07
   800 105.00 126.80      140.     -0.17     0.90

   K AND R -FACTORS-              MONTH  5
   ----------------------------------------
   TOTAL AREAS

          -RUNOFF-                    K        R
STATION  REC.   EST.    AREA        FACTOR   FACTOR
         (MM)   (MM)   (SQ.KM)
   100 100.00 122.57      232.     -0.18     0.88
   200 131.00 103.24       84.      0.27     1.22
   300 107.00 135.63       32.     -0.21     0.87
   400 116.00 110.55      152.      0.05     1.04
   500 132.00 116.79      364.      0.13     1.09
   600 145.00 115.80      444.      0.25     1.18
   700 126.00 114.51     1572.      0.10     1.07
   800 105.00 126.80      140.     -0.17     0.90
```

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
1

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
R=3
# OF STATIONS :       9
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
$>
$>
$>R MWBAL2
TYPE? (1-INIT TEMP,2-INIT PREC,3-INTER PREC,4-RUNOFF)
      (5-ALPHA, 6-INIT RUNOFF)
4
PCT (0 TO INCLUED ALL VARIABLES) ?
.04
# PROBLEM ?
6
DEP. VARIABLE DESCRIPTION ?
RUNOFF (MAY)
TT10  --  STOP
```

```
@T PRINTER.DAT

STEP-WISE MULTIPLE REGRESSION.....#    6     RUNOFF (MAY)

NUMBER OF OBSERVATIONS   755

NUMBER OF VARIABLES       12

CONSTANT TO LIMIT VARIABLES  0.04000

VARIABLE      MEAN      STANDARD
  NO.                   DEVIATION
    1         51.438      22.928     COLUMN NUMBER
    2         30.703       9.894     ROW NUMBER
    3        452.695     180.662     ELEVATION (NW)
    4        459.238     186.470     ELEVATION (SW)
    5        463.377     304.194     ELEVATION (SE)
    6        445.669     184.720     ELEVATION (NE)
    7        367.960      39.621     WOODED AREA X100
    8         15.992      33.629     BARREN AREA X100
    9          6.538      16.954     SWAMP AREA X100
   10          9.282      18.536     FRESH H20 AREA X100
   11          0.132       3.639     SEA AREA X100
   12        126.016      53.553     RUNOFF (MAY)



STEP-WISE MULTIPLE REGRESSION.....#    6     RUNOFF (MAY)



STEPWISE MULTIPLE REGRESSION.....#    6RUNOFF (MAY)

DEPENDANT VARIABLE..... 12
NUMBER OF VARIABLESFORCED.... 0
NUMBER OF VARIABLES DELETED... 0


STEP  1
-------
VARIABLE ENTERED....  9

SUM OF SQUARES REDUCED IN THIS STEP....  0.1093679E+07
PROPORTION REDUCED IN THIS STEP.....  0.5057581E+00

CUMULATIVE SUM OF SQUARES REDUCED.....  0.1093679E+07
CUMULATIVE PROPORTION REDUCED.....  0.5057581E+00  OF  0.2162454E+07

FOR  1 VARIABLES ENTERED
  MULTIPLE CORRELATION COEFFICIENT...  0.7111667E+00
      (ADJUSTED FOR D.F.).....  0.7111667E+00
  F-VALUE FOR ANALYSIS OF VARIANCE...  0.7705455E+03
  STANDARD ERROR OF ESTIMATE.....  0.3767434E+02
      (ADJUSTED FOR D.F.).....  0.3767434E+02

VARIABLE     REGRESSION     STD. ERROR OF      COMPUTED
 NUMBER      COEFFICIENT     REG. COEFF.       T-VALUE

    9      -0.224645E+01    0.809277E-01  -0.277587E+02     SWAMP AREA X100

INTERCEPT   0.140703E+03
```

```
$>R MWBAL6
MONTH (1-12) ?
5
FILE (1-MASTER, 2-CORRELATION, OTHER-STOP) ?
2
# OF VAR TO BE ESTIMATED ?
1

T=1,P=1,E=1,R=2 ------ INIT. TEMP, PREC, EVAP & RUNOFF
P=2             ------ CORRECT PREC BY R FACTOR
P=1,E=1,R=2     ------ EST. INTER. PREC, EVAP & RUNOFF
R=3             ------ CORRECT RUNOFF
R=1             ------ RUNOFF BY REGRESSION EQUATION

VARIABLE ?
R=1
# OF STATIONS :       9
<<<<<    100>>>>>
<<<<<    200>>>>>
<<<<<    300>>>>>
<<<<<    400>>>>>
<<<<<    500>>>>>
<<<<<    600>>>>>
<<<<<    700>>>>>
<<<<<    800>>>>>
```

```
$>R MWBAL7
$>
$>T PRINTER.DAT
```

K AND R -FACTORS- MONTH 5

DIFFERENTIAL AREAS

STATION	-RUNOFF- REC. (MM)	EST. (MM)	AREA (SQ.KM)	K FACTOR	R FACTOR
100	100.00	133.34	232.	-0.25	0.83
200	131.00	95.67	84.	0.37	1.30
300	107.00	138.75	32.	-0.23	0.86
400	116.00	122.68	152.	-0.05	0.96
500	132.00	131.21	364.	0.01	1.00
600	145.00	124.94	444.	0.16	1.12
700	126.00	125.14	1572.	0.01	1.01
800	105.00	138.43	140.	-0.24	0.85

K AND R -FACTORS- MONTH 5

TOTAL AREAS

STATION	-RUNOFF- REC. (MM)	EST. (MM)	AREA (SQ.KM)	K FACTOR	R FACTOR
100	100.00	133.34	232.	-0.25	0.83
200	131.00	95.67	84.	0.37	1.30
300	107.00	138.75	32.	-0.23	0.86
400	116.00	122.68	152.	-0.05	0.96
500	132.00	131.21	364.	0.01	1.00
600	145.00	124.94	444.	0.16	1.12
700	126.00	125.14	1572.	0.01	1.01
800	105.00	138.43	140.	-0.24	0.85

```
$>R MWBALCPY
COPY MONTHLY TEMP, PRECIP, EVAP & RUNOFF
ENTER MONTH (1-12) ?
5
```

(E) VERIFICATION RUNS - NOVA SCOTIA PILOT STUDY :

VERIFICATION RUNS
REGRESSION EQUATIONS & MEAN MONTHLY RUNOFF ESTIMATE
MAY TO NOVEMBER

RIVER JOHN

MONTH = MAY
FLOW = (-2.246) * SWAMP AREA x100 + 140.703
MEAN MONTHLY RUNOFF = 125.4 mm

MONTH = JUNE
FLOW = (-0.851) * SWAMP AREA x100 + (0.547) * ROW NO. + 36.674
MEAN MONTHLY RUNOFF = 56.5 mm

MONTH = JULY
FLOW = (-0.513) * SWAMP AREA x100 + (0.407) * ROW NO. + 19.713
MEAN MONTHLY RUNOFF = 35.3 mm

MONTH = AUGUST
FLOW = (-0.692) * SWAMP AREA x100 + (0.991) * ROW NO. + 17.344
MEAN MONTHLY RUNOFF = 59.1 mm

MONTH = SEPTEMBER
FLOW = (-0.484) * SWAMP AREA x100 + (0.489) * ROW NO. + 16.084
MEAN MONTHLY RUNOFF = 35.7 mm

MONTH = OCTOBER
FLOW = (-1.214) * SWAMP AREA x100 + (1.040) * ROW NO. + 50.820
MEAN MONTHLY RUNOFF = 91.4 mm

MONTH = NOVEMBER
FLOW = (-2.038) * SWAMP AREA x100 + (1.460) * ROW NO. + 92.362
MEAN MONTHLY RUNOFF = 147.0 mm

VERIFICATION RUNS
REGRESSION EQUATIONS & MEAN MONTHLY RUNOFF ESTIMATE
MAY TO NOVEMBER

PEMBROKE RIVER

MONTH = MAY
FLOW = (-2.246) * SWAMP AREA x100 + 140.703
MEAN MONTHLY RUNOFF = 134.7 mm

MONTH = JUNE
FLOW = (-0.851) * SWAMP AREA x100 + (0.547) * ROW NO. + 36.674
MEAN MONTHLY RUNOFF = 50.5 mm

MONTH = JULY
FLOW = (-0.513) * SWAMP AREA x100 + (0.407) * ROW NO. + 19.713
MEAN MONTHLY RUNOFF = 30.3 mm

MONTH = AUGUST
FLOW = (-0.692) * SWAMP AREA x100 + (0.991) * ROW NO. + 17.344
MEAN MONTHLY RUNOFF = 44.7 mm

MONTH = SEPTEMBER
FLOW = (-0.484) * SWAMP AREA x100 + (0.489) * ROW NO. + 16.084
MEAN MONTHLY RUNOFF = 29.2 mm

MONTH = OCTOBER
FLOW = (-1.214) * SWAMP AREA x100 + (1.040) * ROW NO. + 50.820
MEAN MONTHLY RUNOFF = 78.2 mm

MONTH = NOVEMBER
FLOW = (-2.038) * SWAMP AREA x100 + (1.460) * ROW NO. + 92.362
MEAN MONTHLY RUNOFF = 129.9 mm

VERIFICATION RUNS
REGRESSION EQUATIONS & MEAN MONTHLY RUNOFF ESTIMATE
MAY TO NOVEMBER

RIGHTS RIVER

MONTH = MAY
FLOW = (-2.246) * SWAMP AREA x100 + 140.703
MEAN MONTHLY RUNOFF = 139.1 mm

MONTH = JUNE
FLOW = (-0.851) * SWAMP AREA x100 + (0.547) * ROW NO. + 36.674
MEAN MONTHLY RUNOFF = 63.5 mm

MONTH = JULY
FLOW = (-0.513) * SWAMP AREA x100 + (0.407) * ROW NO. + 19.713
MEAN MONTHLY RUNOFF = 39.8 mm

MONTH = AUGUST
FLOW = (-0.692) * SWAMP AREA x100 + (0.991) * ROW NO. + 17.344
MEAN MONTHLY RUNOFF = 66.6 mm

MONTH = SEPTEMBER
FLOW = (-0.484) * SWAMP AREA x100 + (0.489) * ROW NO. + 16.084
MEAN MONTHLY RUNOFF = 40.3 mm

MONTH = OCTOBER
FLOW = (-1.214) * SWAMP AREA x100 + (1.040) * ROW NO. + 50.820
MEAN MONTHLY RUNOFF = 102.2 mm

MONTH = NOVEMBER
FLOW = (-2.038) * SWAMP AREA x100 + (1.460) * ROW NO. + 92.362
MEAN MONTHLY RUNOFF = 164.2 mm

APPENDIX C

NEW BRUNSWICK PHYSIOGRAPHIC DATA SET

SQUARE GRID PROGRAM
PHYSIOGRAPHIC DATA FILE
NEW BRUNSWICK

The physiographic data set for the Province of New Brunswick is stored in nine separate files on the WRB "PDP 11/44" computer at Dartmouth.

The data set was extracted from the National Topographic Maps of Canada with scale of 1:50 000 for 2x2 km**2 grid. The data set includes all the maps that cover New Brunswick and also a number of maps that cover New Brunswick drainages in the Province of Quebec. A total of 119 maps are included in the nine data files.

The maps are stored in the files by map number, i.e. " 21L/2 " with the symbol " ***** " to the right of the map number. The symbol is used to locate maps when using PDP editor. The individual grids are stored by their easting and northing numbers and are identified on the map sheets by the even numbered easting and northing at the centre of the grid.

The maps sheets are stored sequentially in the files by columns starting with the most southwest corner map sheet and working north, map by map. When the most northern sheet is completed the process repetes itself starting at the second most southwest corner.

The grids within a particular map sheet are for the most part stored in a sequential order. The sequence may differ from map sheet to map sheet.

The physiographic parameters extracted from the maps and the format used to store the data are presented in the next section.

PHYSIOGRAPHIC DATA FILE FORMAT
NEW BRUNSWICK

File name : NBGRID00*.DAT * = 1 to 9

File content : These nine files contain the physiographic characteristics and the working area required by the square grid program. Each square occupies one record.

Access method : sequential

Record length : varying (up to 60 characters per line and 4 lines make up a logical record)

Record format : (10I6/10I6/10I6/10I6)

Record order : By National Topographic System Maps Of Canada Numbers. Starting with the most southwest corner and working north.

Record layout :

var #	column	format	description
<< header card >>			
1	1 - 15	A15	no. of National Topographic Map.
<< first card >>			
1	1 - 6	I6	easting number of square
2	7 - 12	I6	northing number of square
3	13 - 18	I6	easting number of square
4	19 - 24	I6	northing number of square
5	25 - 30	I6	area of square - km**2 x 100
6	31 - 36	I6	not used
7	37 - 42	I6	wooded area - km**2 x 100
8	43 - 48	I6	barren area - km**2 x 100
9	49 - 54	I6	not used
10	55 - 60	I6	swamp area - km**2 x 100
<< second card >>			
11	1 - 6	I6	fresh water area - km**2 x 100
12	7 - 12	I6	sea area - km**2 x 100
13	13 - 18	I6	elevation of northwest corner - feet
14	19 - 24	I6	elevation of southwest corner - feet
15	25 - 30	I6	elevation of southeast corner - feet
16	31 - 36	I6	elevation of northeast corner - feet
17	37 - 42	I6	average elevation - feet
18	43 - 48	I6	not used
19	49 - 54	I6	not used
20	55 - 60	I6	not used
<< third card >>			
21-30	1 - 60	10I6	not used
<< forth card >>			
31-40	1 - 60	10I6	used by square grid program

** Remark : the logical record is made up of 4 cards.